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Request for grant of a patent

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Your reference	C573/W
Patent application number *(The Patent Office will fill in this part)*	0300004.9
Full name, address and postcode of the or of each applicant *(underline all surnames)*	UNOVA U.K. Limited 26 Temple Street Aylesbury Buckinghamshire HP20 2RQ
Patents ADP number *(if you know it)*	07328529001
If the applicant is a corporate body, give the country/state of its incorporation	England
Title of the invention	Grinding Wheel Monitoring
Name of your agent *(if you have one)*	Keith W Nash & Co
"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	90-92 Regent Street Cambridge CB2 1DP
Patents ADP number *(if you know it)*	1206001
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If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application	Number of earlier application / Date of filing *(day / month / year)*
Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if: a) any applicant named in part 3 is not an inventor, or b) there is an inventor who is not named as an applicant, or c) any named applicant is a corporate body. See note (d))*	Yes a)

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Priority documents

Translations of priority documents

Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*

Request for preliminary examination and search *(Patents Form 9/77)*

Request for substantive examination *(Patents Form 10/77)*

Any other documents *(please specify)*

11. I/We request the grant of a patent on the basis of this application.

Signature

Date 31.12.2002

Keith W Nash & Co, Agents

12. Name and daytime telephone number of person to contact in the United Kingdom

Mr Nash (01223) 355477

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C573/W

Title: Grinding Wheel Monitoring

Field of invention

This invention concern methods and apparatus for monitoring the failure of grinding wheels especially Electroplated CBN grinding wheels.

Background to the invention

It is possible to replace the grinding material on the hub of a grinding wheel, particularly to re-electroplate a CBN wheel around the hub and the cost of such a refurbishment of an existing hub is far less than the cost of replacing the wheel in its entirety. However if all of the grinding material is stripped away from any part of the hub during the grinding process, the hub cannot normally be refurbished in this way, and in particular cannot be replated with CBN material. In this event, the wheel has to be scrapped. It should therefore be of financial benefit to an end user of grinding wheels, particularly Electroplated CBN wheels, to be able to predict the point in time just prior to when the grinding material is liable to be stripped from the hub and to allow the machine to be stopped before the wheel is irreparably damaged.

Previously it has been thought that the most suitable method for monitoring a grinding wheel was via the increased in grind power which arises as the wheel wears. Past tests have shown that the increase in grind power over the life of the wheel to be about 50% but most of this increase is found to occur during the machining of the last half to 1% of the normal life expectancy of the wheel. Thus if the normal life of a wheel is expressed in terms of the number of similar workpieces which can be ground by the wheel before it is worn down to the hub, and the normal life is say 4,000 workpieces, then the 50% increase in grind power is only found to occur during the last 20 or 30 workpieces.

This pattern is typical for a grinding wheel performing cylindrical grinding in which the grinding face of the wheel is plain, ie the grinding process is substantially uniform over the width of the wheel.

For many grinding processes, the face of the wheel is not plain, but is required to include at least one and sometimes two or three peripheral ridges which it is found tend to wear away more quickly than the remaining surface of the wheel. This is particularly common when grinding side walls with undercuts. Each of the rims of the grinding wheel have to remove considerably more metal than the central region of the wheel and the power increase pattern for such a wheel when performing this type of grinding is rather different and there is only a minimal increase in power before the grinding material is completely stripped from the wheel due to the wheel wear occurring disproportionally over the width of the wheel.

It is an object of the present invention to provide an alternative method of monitoring a grinding wheel's performance which provide a reliable warning of when the grinding material, particularly Electroplate CBN material, is found to wear away, even when the wear is excessive and uneven over the width of the wheel.

Summary of the invention

According to the present invention a method of monitoring the wear of a grinding wheel comprises the step of measuring the force exerted between the wheel and the workpiece, measured normal to the grinding face of the wheel at the point of contact between the wheel and workpiece, and a warning signal indicating the wheel should be withdrawn from service is generated when the measured force exceeds a predetermined threshold value.

In a preferred method embodying the invention, a signal indicative of the normal grinding force is obtained by measuring the force exerted by the linear wheelfeed drive urging the wheel into grinding engagement with the workpiece. Where the linear wheelfeed drive is powered by an electrically powered motor, the torque developed by which is proportional

to the normal force between the wheel and workpiece, and is in turn proportional to the electrical power drawn by the motor from its power supply, force measurement may be achieved by measuring the power flow to the motor.

Where the power supply maintain a substantially constant EMF, the power draw (and therefore normal force) is proportional to the current drawn by the motor from its power supply.

According to a further development of the invention, the force value measured during a grinding process may be compared with the value measured during the grinding process performed on a preceding workpiece, and a warning signal is generated if the preceding force value differs from the current force value by more than a predetermined amount.

According to a still further development of the invention, the force value measured during the current workpiece grinding process may be compared with a mean force value computed from the plurality of preceding workpiece grinds and a warning signal is generated is the mean force value differs from the current force value by more than a predetermined amount.

According to a still further development of the invention, the method includes the step of resetting a timing device at one point during each grinding process, and the force measuring is performed for a period of time determined by the timing device from the reset point, the period of time corresponding to the time during which a part of the grinding wheel is liable to the greatest wear during grinding, is in grinding engagement with the workpiece.

Where the cylindrical surface of a grinding wheel includes an angular ridge for grinding an undercut in a workpiece, which ridges the part of the wheel surface which performs more work than the remainder of the wheel surface, the force measurement is preferably performed only during that portion of the grinding process on each workpiece, during which only the annular ridge is in contact with the workpiece.

According to a still further development of the invention, the peak value of the normal grinding force is measured during at least part of the workpiece grinding process and the wheel is moved from surface when the measured peak force value exceeds the predetermined value or exceeds a preceding peak force value by a predetermined amount.

In a preferred arrangement, data logging of force is triggered X seconds after the start of grinding each workpiece, and disabled Y seconds after the start of grinding. When grinding the side wall of a crankpin, typically values of X and Y would be 3 seconds and 26.5 seconds respectively.

The invention thus provides a method of monitoring grinding wheel wear, in which the power to the linear drive which advances and maintains the grinding wheel in grinding contact with a workpiece is monitored during the same part of the grinding process performed on each of a succession of similar workpieces, and a warning signal is generated immediately the power demand exceeds a predetermined value.

The warning signal may be employed to sound an alarm to alert a machine operator that a wheel change is required, and/or may be employed to instigate wheel withdrawal to disengage the wheel from the workpiece to prevent further wear occurring and/or may instigate a wheel withdrawal and/or automated replacement by which the wheel is automatically withdrawn from service, demounted from its driving spindle and replaced with a fresh wheel ready to take over the grinding from the worn wheel.

The invention is of particular application to the monitoring of the wear of Electroplated CBN grinding wheels and is not only relevant to formed wheels but is also applicable to flat-faced grinding wheels which are sometimes used to grind sidewalls and diameters.

The invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is a graph showing the normal force acting on one of two grinding wheels for an entire grind cycle;

Figure 2 is an enlargement of the left hand end of the graph of Figure 1;

Figure 3 is a graph showing the 9 peak forces generated by a side wall grind;

Figure 4 shows the increase in normal force on the side wall grind during the last 7 shafts ground using the left hand wheel of a pair both designed to provide undercuts in a crankpin;

Figure 5A and Figure 5B respectively show part of the left hand wheel and part of the right hand wheel of a pair of Electroplate CBN grinding wheels, each having a radial protrusion for grinding an undercut;

Fig 6 shows a flat faced grinding wheel grinding a workpiece, and

Fig 7 is a flow diagram of a monitoring system embodying the invention.

The graphs in Figures 1 to 4 were obtained from measuring the normal force during the grinding of a crankshaft crankpin using Electroplated CBN wheels such as shown in Figure 5. The two wheels were used in succession with each wheel performing half of each plunge. The undercut portion of both wheels performed far more work than the remainder of the wheel and therefore in this situation it is important to monitor the grind in a period where only the undercut portion of the wheel is cutting. The normal force was monitored for the whole of each grind but data was only extracted during the first plunge of each wheel as this was grinding long side walls.

The graph in Figure 1 shows the left hand wheel's normal force for the entire grind cycle. The four plunges for the pins are marked due to the cycling effect of the motor force required when grinding a pin. The rapid advances and retracts, in between plunges, can be seen as the large peaks on the normal force plot. The section of the plot that is of most interest can be clearly observed at the start of the grind and is circled in Figure 1.

The magnified view of the circled section in Figure 1 is shown in Figure 2.

The same data was acquired for the right hand wheel over the full grind cycle.

In Figure 2 it will be seen that the side wall grind, in this case, consists of 11 force cycles followed by the large force required to grind the diameter. This data was taken for every shaft over nearly 1,000 shafts at the end of which the CBN material on the left hand wheel's undercut had become stripped completely to the hub. Graphs were compiled using the values of peak force from the cycles that make up the side wall grind. The first two force cycles were ignored as they were often very small or non-existent due to the variable side wall stock. The graph in Figure 3 shows the 9 peak forces generated by the side wall grind.

It will be seen that the peak forces for the side wall grind remain relatively constant over the lift of the grinding wheel until just prior to wheel failure where the forces increased dramatically. The X-axis of the graph is the crankshaft number and in this case something in excess of 2,900 crankshafts were ground by the grinding wheels but the plot is only from wheel 1950 through to 2,913 which was when the wheel failed. It will be seen that a huge peak in grinding force occurred just after 2,900 shafts had been ground when the peak normal force which had previously been of the order of 500 Newtons rose to in excess of 3,000 Newtons.

The graph of Figure 4 shows the increase in the normal force on the side wall grind, during the last 7 shafts ground, ie from 2,006 to 2,013 when wheel failure occurred. From Figure 4 it will be seen that the side wall grind forces increased dramatically over

the last 5 shafts ground. If a side wall force limit of 1,000 Newtons had been set, then a warning signal would be displayed or sounded at shaft 2,911 which would have been two shafts prior to complete wheel failure. The amount of Electroplating left on the hub at that stage is probably just sufficient to allow the wheel to be replated and yet to obtain maximum life from the wheel.

Since spurious force peaks can occur during grinding, it is important to monitor the peak normal force during the same portion of each grind cycle since any response to a spurious peak occurring during another part of the grind cycle will cause unwanted stoppages.

As stated previously the invention is equally applicable to flat faced grinding wheels such as shown in Fig 6. When grinding using a flat faced wheel the edge region of the wheel will perform greater amounts of work than the central region of the wheel. The sides of the wheel will therefore fail before the remainder of the wheel. This type of application would therefore still require the windowing approach provided by the invention.

For most grinding operations there will be a rapid advance and a rapid retract of the wheelfeed mechanism. This produces a large force peak that needs to be eliminated from the data being monitored. Again this would require the windowing approach.

Fig 6 shows by way of a flow diagram the monitoring and decision making steps of a wheel monitoring system embodying the invention. The system assumes a formed CBN wheel to be grinding a formed region of a crankshaft and a linear motor wheelfeed.

The monitoring device is brought into play when the side of the wheel (the sidewall) that performs the most work in use. Therefore the monitoring device is activated once the machine starts a sidewall feed for a journal grind.

It is to be noted that wear cannot so readily be monitored when pin grinding since in order to grind a pin the wheelhead must cycle forward and backwards. The forwards and

backwards motion masks the grinding force data on the linear motor. At the end of a sidewall feed the monitoring is deactivated.

The signal monitored is the torque/force feedback value, direct from the linear motor drive unit. The values used are a percentage of the maximum linear motor current at standstill. This parameter is monitored every 30 mins and compared against a preset limit value. As the signal monitored tends to have some noise on it, then the value used to compare against the preset limit can be obtained by averaging the values of, for example, five sidewall feed samples.

If the preset limit is exceeded over the sidewall feeds which are to be averaged, then at this stage the device informs the machine control to immediately suspend grinding and display a message regarding imminent wheel failure.

A new wheel can then be mounted and grinding can continue.

The removed wheel can be sent for replating.

The flow diagram of Fig 6 shows the process just described.

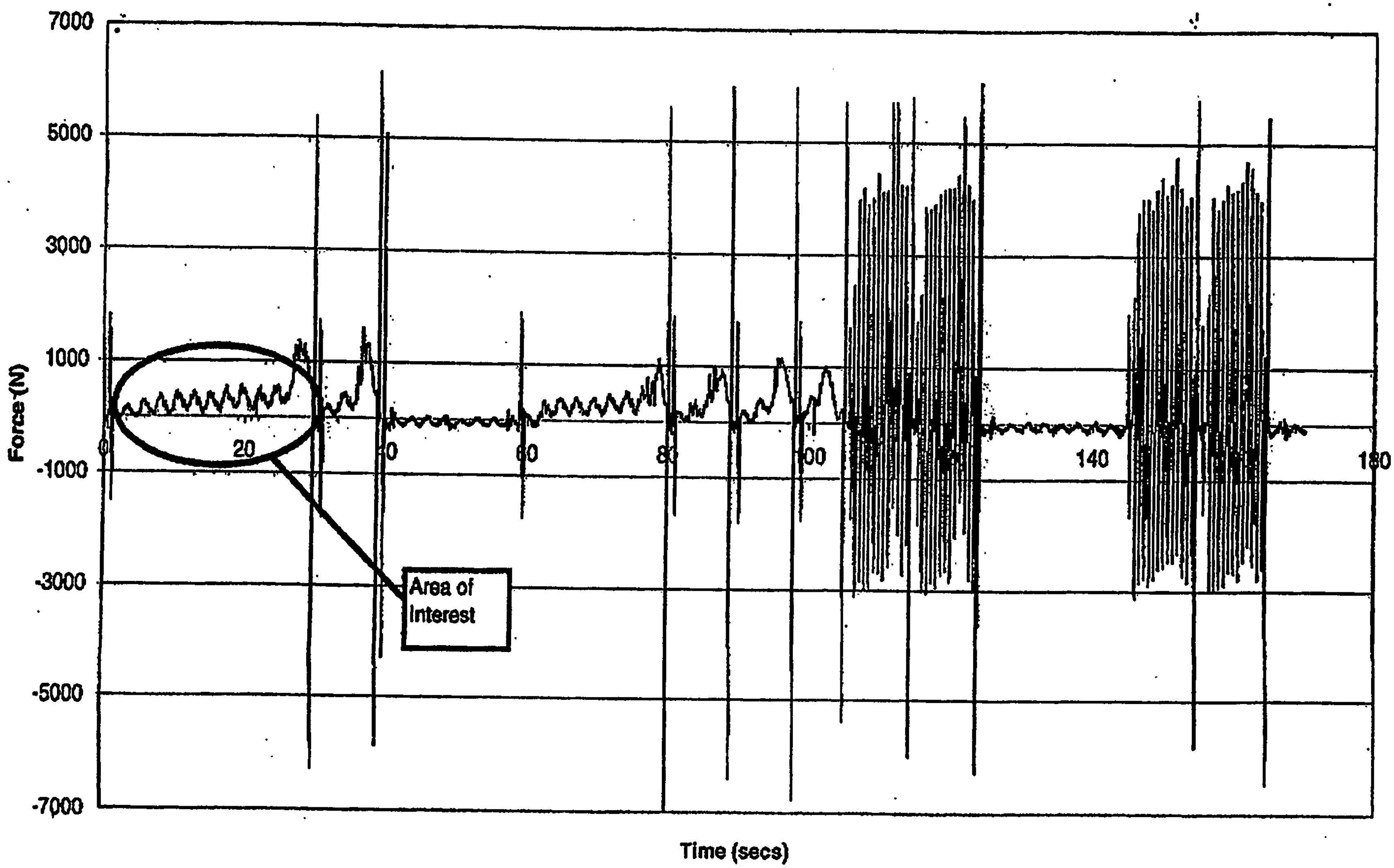
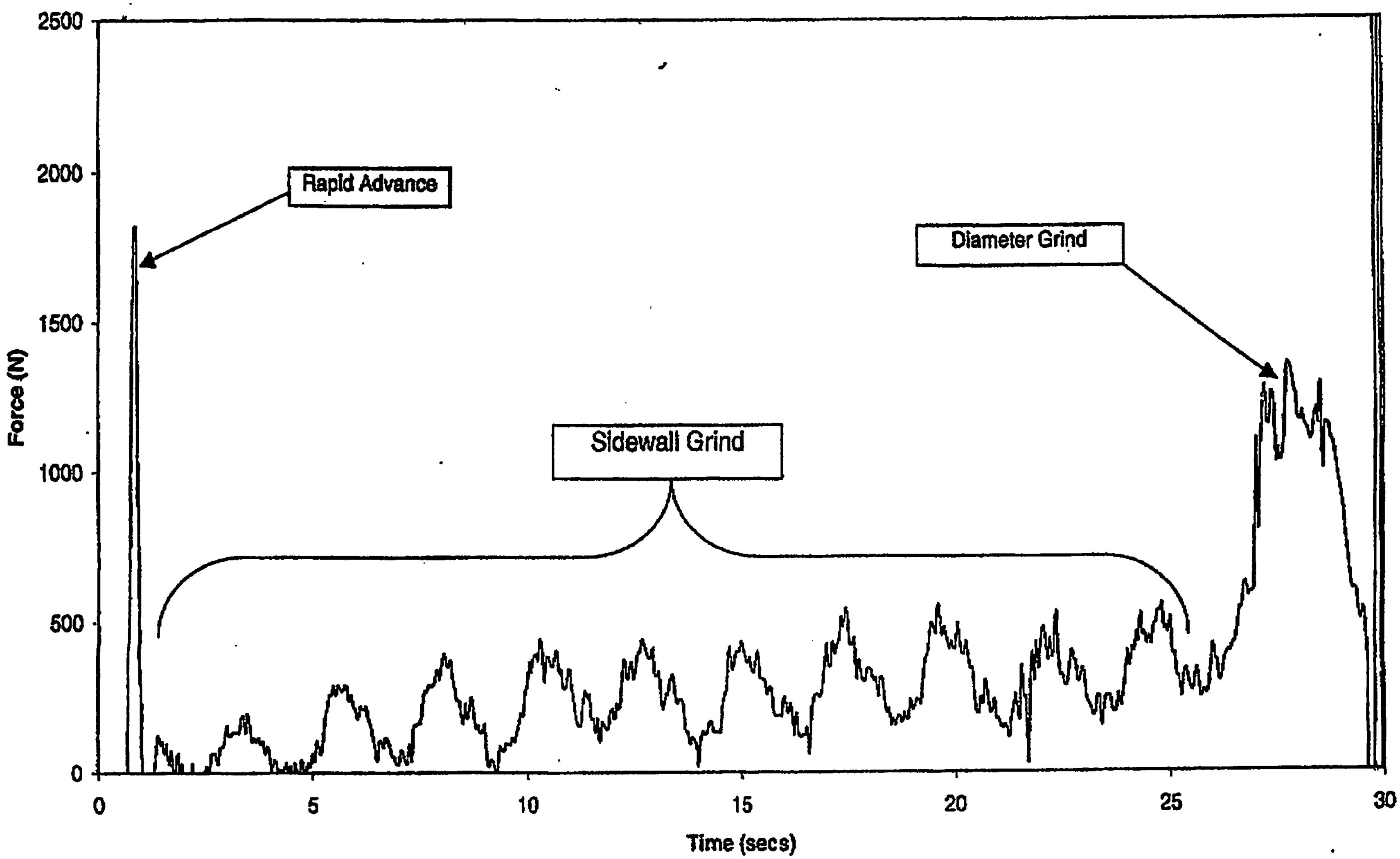

7000
5000
3000
1000
-1000
-3000
-5000
-7000
Force (N)
0
20
40
60
80
100
140
180
Time (secs)
Area of Interest

FIG 1.



Rapid Advance
Diameter Grind
Sidewall Grind
Force (N)
2500
2000
1500
1000
500
0
0
5
10
15
20
25
30
Time (secs)

FIG 2

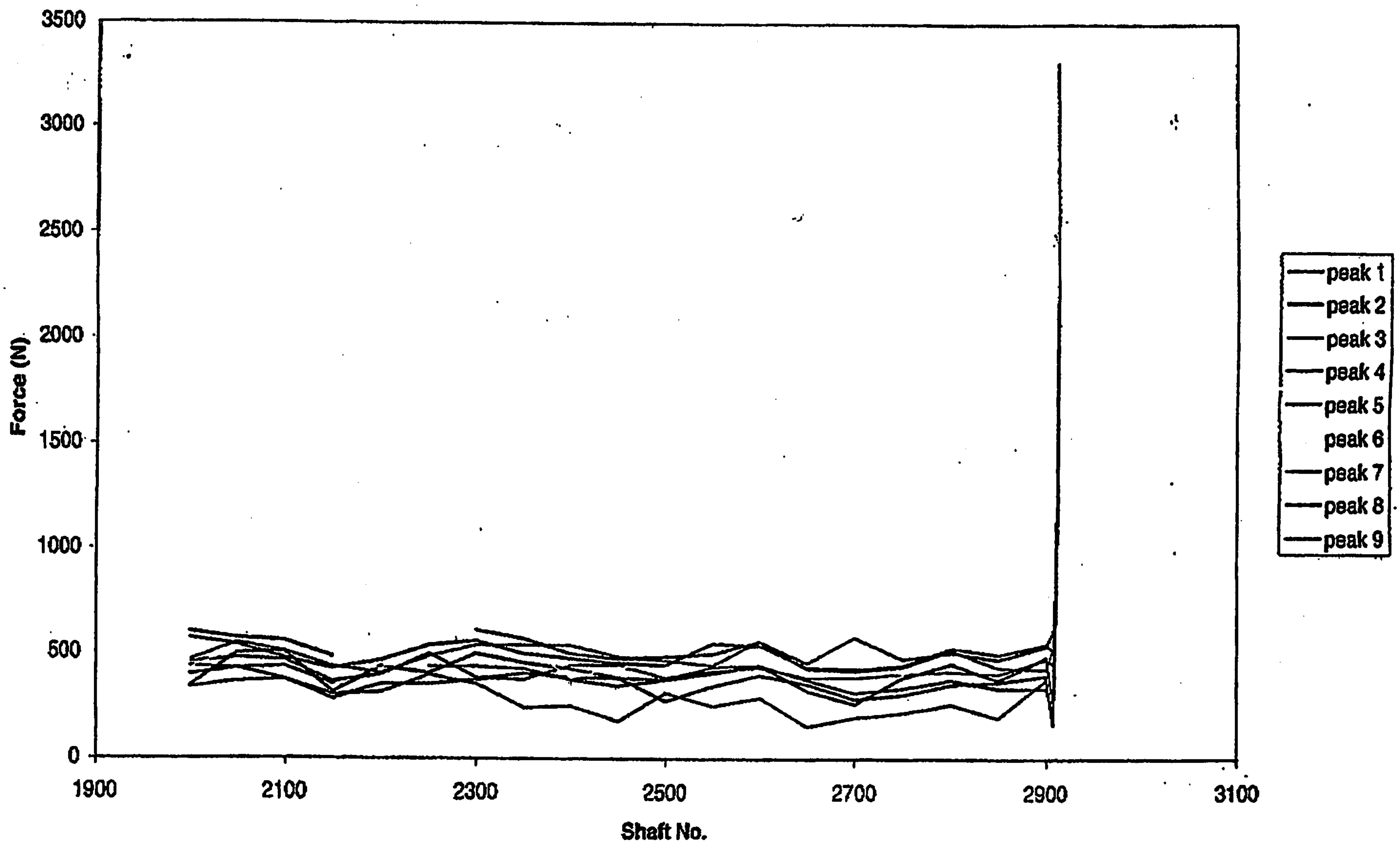
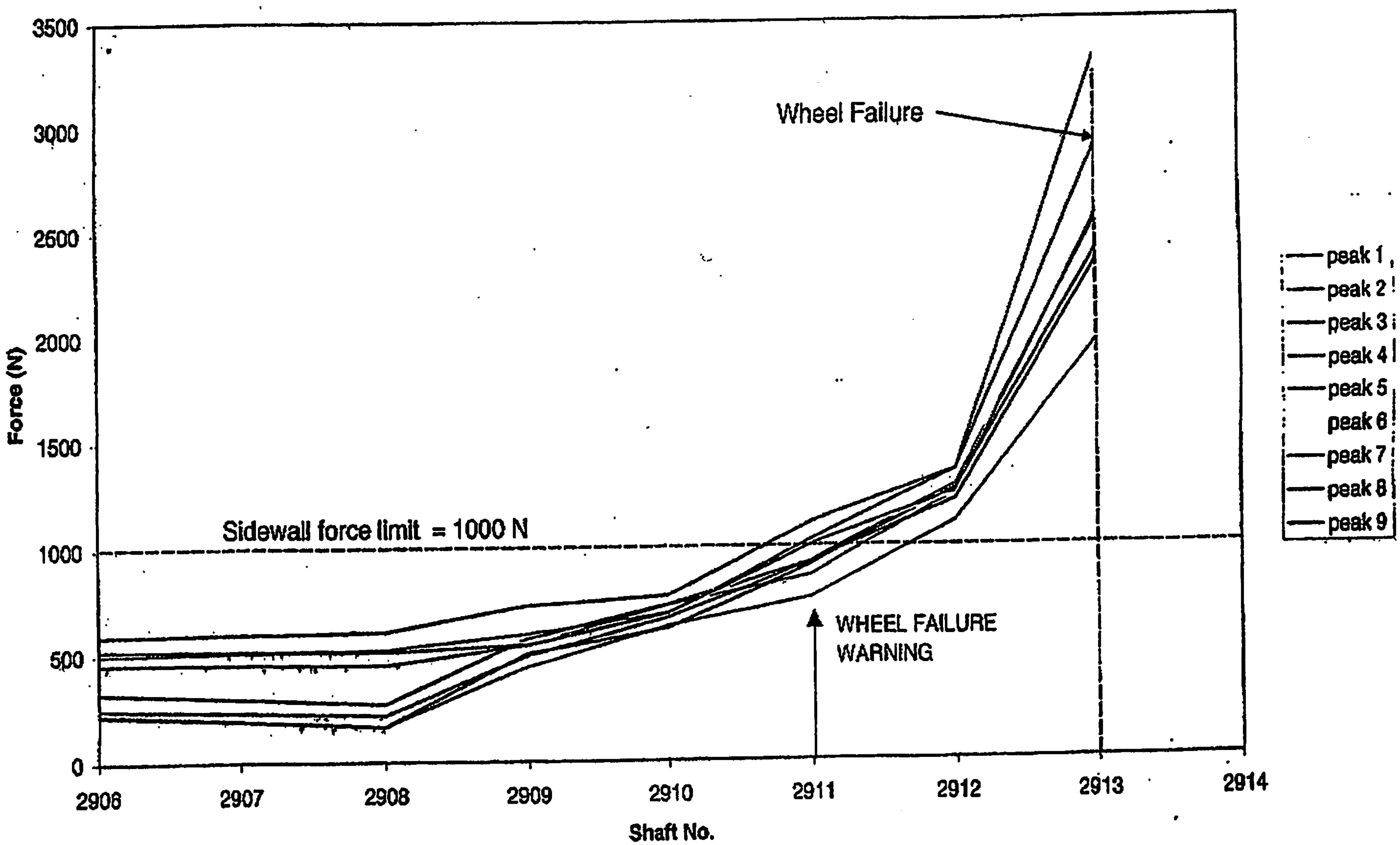

Force (N)
3500
3000
2500
2000
1500
1000
500
0
1900
2100
2300
2500
2700
2900
3100
Shaft No.
peak 1
peak 2
peak 3
peak 4
peak 5
peak 6
peak 7
peak 8
peak 9

FIG 3

4/6



Force (N)
3500
3000
2500
2000
1500
1000
500
0
Wheel Failure
Sidewall force limit = 1000 N
WHEEL FAILURE
WARNING
2906
2907
2908
2909
2910
2911
2912
2913
2914
Shaft No.
peak 1
peak 2
peak 3
peak 4
peak 5
peak 6
peak 7
peak 8
peak 9

FIG 4

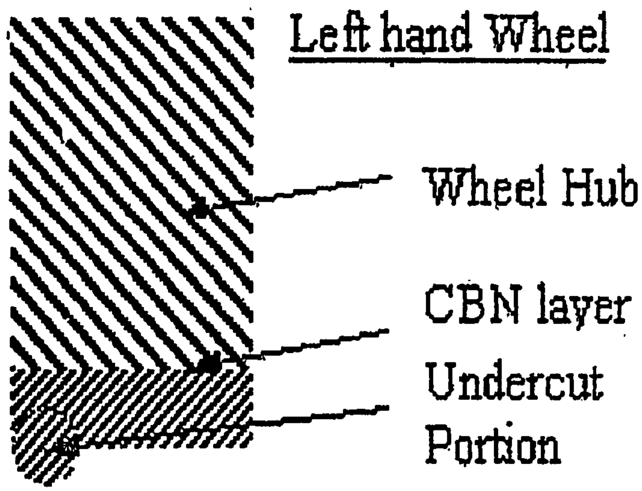

Left hand Wheel
Wheel Hub
CBN layer
Undercut
Portion

FIG 5A

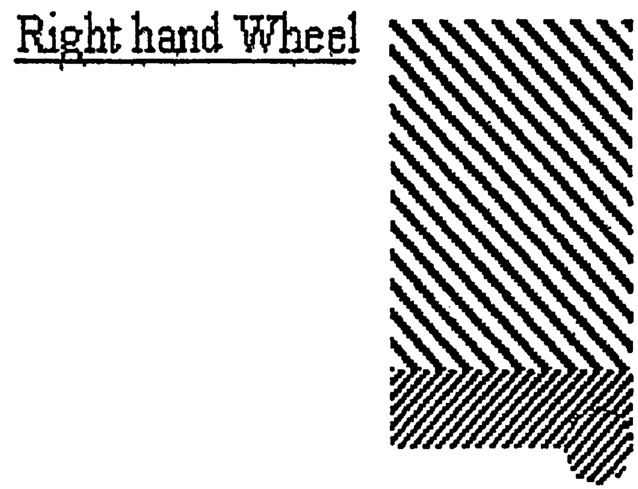

Right hand Wheel

FIG 5B

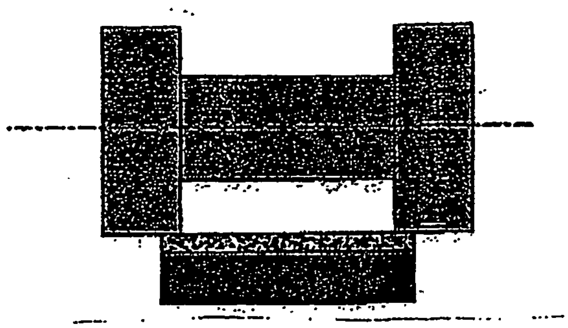


FIG 6

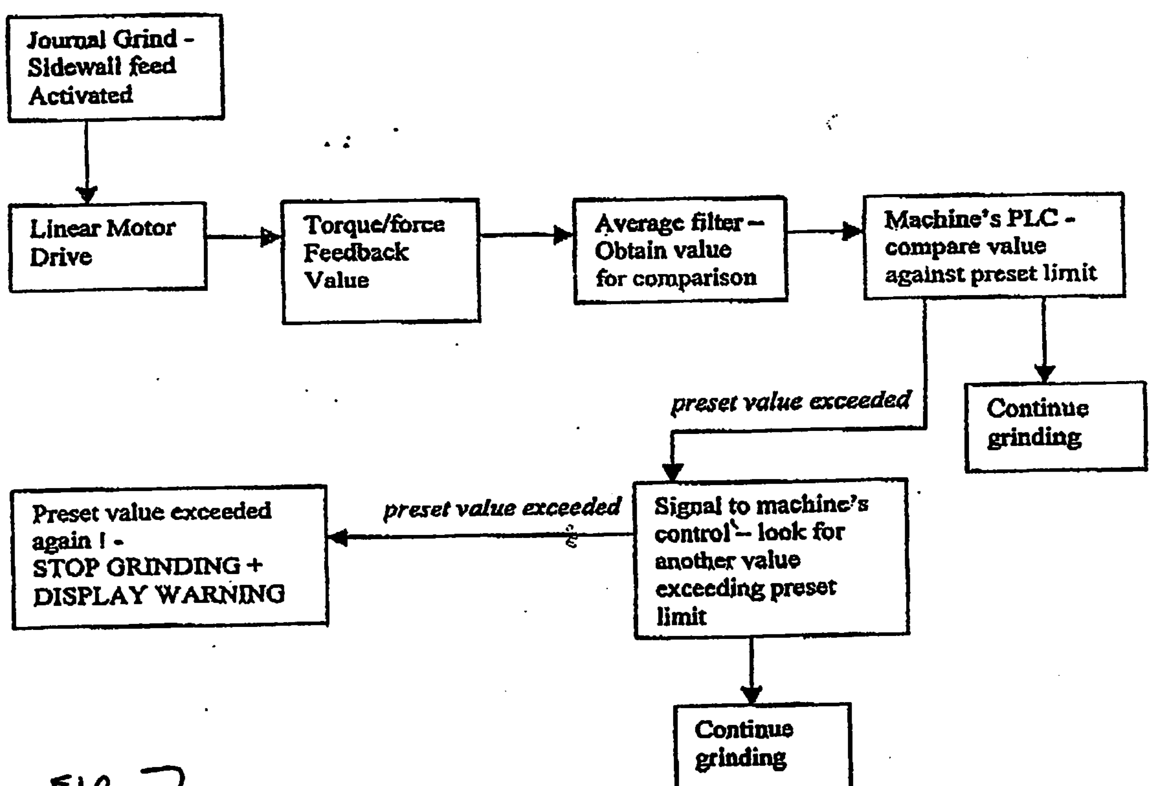

Journal Grind - Sidewall feed Activated
Linear Motor Drive
Torque/force Feedback Value
Average filter – Obtain value for comparison
Machine's PLC - compare value against preset limit
preset value exceeded
Continue grinding
Preset value exceeded again ! - STOP GRINDING + DISPLAY WARNING
preset value exceeded
Signal to machine's control – look for another value exceeding preset limit
Continue grinding

FIG 7